

# IMPROVED MASK REVISION ID CODE CIRCUIT

## TECHNICAL FIELD

5           The present invention relates generally to integrated circuits, and more particularly to circuits for indicating mask versions and/or revisions of an integrated circuit.

## BACKGROUND OF THE INVENTION

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10           A typical integrated circuit may be formed by patterning or otherwise altering various layers according to particular masks. A collection of masks for forming an integrated circuit is often referred to as a mask set. An integrated circuit mask may take various forms. As one example, a mask may be a lithographic mask for selectively exposing a resist material to a radiation source, such as light having a particular frequency. In addition or alternatively, a mask may include a pattern that is programmed into a machine that may provide a beam of  
15           particles, such as electrons. Such a beam may raster a pattern across an integrated circuit layer according to such a programmed pattern.

20           While one particular mask set can be used in the production of an integrated circuit, such as mask set may be revised as changes to a device are made. In many cases, a mask revision may not substantially change the overall operation of an integrated circuit. Thus, it may not be possible to determine which particular mask set was used to fabricate an integrated circuit without deprocessing the device. Deprocessing can be time consuming, involve the use of various noxious chemicals, and can render a device non-operational.

25           At the same time, it is desirable to know the particular mask set for a device for reliability and other tracking reasons. Accordingly, in order to identify a mask set for an integrated circuit without having to resort to deprocessing, many integrated circuits include

readable mask revision identification (ID) codes. By electronically reading values generated at a particular pin, or pins, it can be possible to identify a particular mask set.

One conventional approach to generating mask revision ID codes will now be described with reference to a number of diagrams.

5 Referring now to FIG. 7, a mask revision ID code circuit is shown in a block diagram and designated by the general reference character **700**. A circuit **700** may include a number of mask ID bit circuits **702-0** to **702-n**, where  $n$  is an integer. Each mask ID bit circuit (**702-0** to **702-n**) may receive two different voltages as inputs: VGND and VPWR. Such input voltages may be power supply voltages, as but one example. Each mask ID bit circuit (**702-0** to **702-n**) may also provide an output value SA0 to SAn. Output values (SA0 to SAn) may provide a mask revision ID code. Thus, mask ID bit circuits (**702-0** to **702-n**) may be configured so that each different mask revision can result in a different set of output values (SA0 to SAn).

FIG. 8 illustrates one example of a conventional mask ID bit circuit **800**. A mask ID bit circuit **800** may include a number of links, shown as **802-0** to **802-4**, arranged in series. Each link (**802-0** to **802-4**) may be formed from a different layer of an integrated circuit. As but one example, a link **802-0** may be formed from a layer comprising amorphous and/or polycrystalline silicon (polysilicon), while links **802-1** to **802-4** may be formed from increasingly higher levels of interconnect. That is, link **802-1** may be formed from a “metal 1” layer, link **802-2** may be formed from a “metal 2” layer, etc. An output value SAn may be provided at a sense node **804**.

In FIG. 8, each link is represented as a double throw switch. In this way, a sense node may be connected to either a first potential (VGND) or a second potential (VPWR)

according to the arrangements of the links.

Examples of conventional links are shown in FIG. 9. FIG. 9 includes a series of top plan views of links, starting with a lower integrated circuit layer link **802-0** and ending with a higher integrated circuit layer link **802-4**. It is understood that each layer may be electrically  
5 connected with one another by way of a vertical contact and/or via. Such electrical connections between layers are shown as dashed lines in FIG. 9.

In the conventional approach of FIG. 9, each link (**802-0** to **802-4**) may include conductive lines **902-00/01** to **902-40/41**. Each conductive line (**902-00** to **902-41**) may include a downward contact **904-00/01** to **904-40/41** and an upward contact **906-00/01** to  
10 **906-40/41**. It is understood that a downward contact (**904-00** to **904-41**) may connect one layer with a lower layer. Similarly an upward contact (**906-00** to **906-41**) may connect one layer with a higher layer. For example, in the particular arrangement of FIG. 9, downward contacts **904-10** and **904-11** can correspond to upward contacts **906-00** and **906-01**.

In FIG. 9, conductive line **902-00** may have a downward contact **904-00** to one  
15 potential (VGND), while conductive line **902-01** may have a downward contact **904-10** to another potential (VPWR). Further, in the example of FIG. 9, a conductive line **902-40** may provide an output value SAn at a sense node **804**.

To better understand vertical connections between layers, a side cross sectional view is presented in FIG. 10. FIG. 10 shows a potential VGND connected to conductive line **902-00** by way of downward contact **904-00**. Various connections between conductive lines **902-00**, **902-10** and **902-20** are shown in the cross sectional view.  
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It is noted that the arrangement of FIGS. 8 and 9 can represent a mask bit ID circuit in an initial (unmodified) state. That is, such a mask bit ID circuit may represent an initial set

of masks for an integrated circuit. In an unmodified state, an output value SAN will be low (e.g., VGND), as the series of links (802-0 to 802-4) provide a conductive path between VGND and a sense node 804. As a mask is revised, a change may also be made in the mask bit ID circuit to change the output value SAN provided by such a circuit. A revised mask bit ID circuit is shown in FIGS. 11 and 12.

In FIG. 11, a link 1102-2 has been modified to reflect a change in a mask set. As a result, if a link 1102-2 can be conceptualized as a double throw switch, once modified, the switch can be considered to be thrown to connect to a potential VPWR, rather than a potential VGND (the unmodified state). Once such a change is made, an output value SAN can be a logic high value, as a modified conductive path is created between a potential VPWR and a sense node 804.

FIG. 12 shows top plan views corresponding to the various links of FIG. 11. As shown, a modified link 1102-2 may include one conductive line 1202-20 that includes a single downward contact 904-20, and another conductive line 1202-21 that includes a single downward contact 904-21, but conductively connects to a higher link with upward contacts 906-20 and 906-21. In this way, a low logic value (VGND) can be isolated from a sense node 804, while a high logic value (VPWR) can be redirected to a sense node 804, thereby indicating a mask change/revision.

A drawback to conventional approaches, such as that described above, can be the limited number of mask revisions that may be expressed for a given set of mask bit ID circuits. In particular, for  $n$  mask ID bits, only  $n$  mask revisions may be expressed. Such a limitation can exist because once a change is made to a mask ID bit, the bit value may not be changed back unless the same mask layer is changed. Consequently, to account for higher

numbers of mask revisions, it may be necessary to include more and more mask ID bit circuits.

It would be desirable to arrive at some way of providing a mask ID code circuit that can allow for an increased number of possible mask revision codes for a given number of mask ID bit circuits than conventional approaches. It would also be desirable that such a solution does not substantially increase the overall area required for such a mask ID code circuit.

### SUMMARY OF THE INVENTION

10 According to one embodiment of the present invention, a mask identification circuit may include  $n$  mask ID bit circuits that provide an  $n$ -bit mask ID code. Unlike conventional approaches, an  $n$ -bit ID code according to the embodiments can provide  $2^n$  different mask ID codes with any combination of mask layer changes. Consequently, more mask changes may be accommodated than conventional approaches.

15 According to one aspect of the embodiments, each mask ID bit circuit may include signal paths connected to two different potentials. In one mask version, a mask ID bit circuit provides a first potential to a sense node. In another mask version, signal paths may be cross coupled to provide a second potential to a sense node. In yet another mask version, signal paths maybe cross coupled once again to provide the first potential to a sense node once  
20 again.

According to another aspect of the embodiments, each mask ID bit circuit may include a number of links arranged in series. Each link can include two inputs and two outputs. In a first configuration, two inputs may be directly coupled to two outputs, while in

a second configuration, two inputs may be cross coupled to two outputs.

According to another aspect of the embodiments, a link may include two conductive lines. In a first configuration, two conductive lines may have a first orientation. In a second configuration, two conductive lines may have a different orientation. Different orientations  
5 may be perpendicular to one another.

According to another aspect of the embodiments, a conductive line of a link may be connected to a conductive line of another link by one contact in both a first configuration and a second configuration.

According to another aspect of the embodiments, each link may be connected to a  
10 lower link by downward contacts that are diagonal to one another. Further, each link may be connected to a higher link by upward contacts that are diagonal to one another.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a mask identification (ID) bit circuit according to  
15 one embodiment.

FIG. 2 is a series of top plan views of showing a mask ID bit circuit according to one embodiment.

FIG. 3 is a schematic diagram of a mask ID bit circuit after a first modification according to one embodiment.

20 FIG. 4 is a series of top plan views of showing a mask ID bit circuit after a first modification according to one embodiment.

FIG. 5 is a schematic diagram of a mask ID bit circuit after a second modification according to one embodiment.

FIG. 6 is a series of top plan views of showing a mask ID bit circuit after a second modification according to one embodiment.

FIG. 7 is a block diagram of a mask revision ID code circuit.

FIG. 8 is a schematic diagram of a conventional mask ID bit circuit.

5 FIG. 9 is a series of top plan views of showing a conventional mask ID bit circuit.

FIG. 10 is a side cross sectional view of a conventional mask ID bit circuit.

FIG. 11 is a schematic diagram of a conventional mask ID bit circuit after a modification.

10 FIG. 12 is a series of top plan views of showing a conventional mask ID bit circuit after a modification.

#### DETAILED DESCRIPTION OF THE EMBODIMENTS

Various embodiments of the present invention will now be described with reference to a number of diagrams. The embodiments include a mask identification (ID) code circuit and a mask ID bit circuit. According to one embodiment, a mask ID bit circuit may represent more than one change in a mask. Consequently, the number of revisions represented by a mask revision ID code circuit may not be limited to the number of mask ID bit circuits.

20 In one arrangement, a mask revision ID code circuit may have the same general layout as that set forth in FIG. 7. However, unlike conventional approaches, each mask ID bit circuits within such a circuit **700** may be capable representing multiple changes in a mask.

Referring now to FIG. 1, a mask ID bit circuit **100** according to one embodiment is shown in a schematic diagram. A mask ID bit circuit **100** may be conceptualized as including a number of links, shown as **102-0** to **102-4**, arranged in series. In one approach,

each link (102-0 to 102-4) may be formed from a different layer in an integrated circuit. More particularly, each link may be formed by patterning a different conductive layer. As but one example, one or more lower layers, such as 102-0, may comprise polycrystalline silicon, while one or more higher layers may comprise higher levels of interconnect, or the like.

A link (102-0 to 102-4) may have two inputs and at least one output. For example, in FIG. 1, a link 102-1 may have inputs 104-0 and 104-1 and outputs 106-0 and 106-1. Inputs (104-0 and 104-1) and outputs (106-0 and 106-1) may be directly coupled or cross-coupled. In a directly coupled case, an input 104-0 may be coupled to an output 106-0, while an input 104-1 may be coupled to an output 106-1. In a cross coupled case, an input 104-0 may be coupled to an output 106-1, while an input 104-1 may be coupled to an output 106-0.

FIG. 1 shows an example where links (102-0 to 102-4) can be considered to have directly coupled inputs and outputs. As will be described in more detail below, to indicate a mask change/revision, a link (102-0 to 102-4) may be changed from a directly coupled configuration to a cross coupled configuration, thereby indicating a mask revision/change. Still further, to indicate another mask change/revision, another link (102-0 to 102-4) may be changed from a directly coupled configuration to a cross coupled configuration.

In this way, links (102-0 to 102-4) of a mask ID bit circuit 100 may form signal chains that can provide a particular predetermined potential to a sense node 108. In the example of FIG. 1, a signal chain may provide a conductive path from a potential VGND to a sense node 108. However, if a link is changed into a cross coupled configuration, a signal chain may provide a conductive path from a potential VPWR to a sense node 108. Still further, if another link is changed to a cross coupled configuration, a signal path would



switch once more, again providing a conductive path from a potential VGND to a sense node 108. In this way, a mask ID bit circuit 100 may represent more than one change in a mask.

In the embodiment of FIG. 1, a link (102-0 to 102-4) may be conceptualized as including two double throw switches. When both switches are in one state, a link (102-0 to 102-4) may provide direct coupling between an input and output. When both switches are in another state, a link (102-0 to 102-4) may provide cross coupling between an input and an output.

Referring now to FIG. 2, a series of top plan views of links (102-0 to 102-4) according to one embodiment are shown. Each link (102-0 to 102-4) may be formed on a particular integrated circuit layer, and connected to another link by way of vertical connections. Such vertical connections may include, without limitation, contact like structures, including vias. For example, a link 102-0 may be formed on a lower integrated circuit layer than links 102-1 to 102-4, while a link 102-1 may be formed on a lower integrated circuit layer than links 102-2 to 102-4.

Electrical connections between layers are shown as dashed lines in FIG. 2.

According to the embodiment of FIG. 2, a link (102-0 to 102-4) may include conductive lines 202-00/01 to 202-40/41. Further, a conductive line (202-00 to 202-41) may include a downward contact 204-00/01 to 204-40/41 and an upward contact 206-00/01 to 206-40/41.

It is noted that in the example of FIG. 2, downward contacts (204-00 to 204-41) and upward contacts (206-00 to 206-41) have an alternating diagonal relationship to one another. For example, in link 102-0 downward contacts 204-00 and 204-01 are situated diagonal to one another. Similarly, upward contacts 206-00 and 206-01 are diagonal with one another.

In a next higher link **102-1**, upward contacts **206-10** and **206-11** are diagonal to one another, but situated in an alternating position to downward contacts **206-00** and **206-01** of a lower link **102-0**. This is in contrast to a conventional approach, such as that shown in FIG. 9, which may not include contacts in a diagonal arrangement.

5           An upward contact (**206-00** to **206-41**) may correspond to a downward contact (**204-00** to **204-41**) of a next higher layer. For example, in the particular arrangement of FIG. 2, upward contacts **206-00** and **206-01** can correspond to downward contacts **204-10** and **204-11**.

10           In this way, links providing signal paths that may be directly or cross coupled, can be formed on different layers of an integrated circuit.

As noted above, the example of FIGS. 1 and 2 shows an example of a links that are directly coupled. FIGS. 3 and 4 show how a link may be changed from a directly coupled state to a cross coupled state, to thereby provide a different value at a sense node **108**.

15           FIG. 3 shows a schematic diagram of a mask ID bit circuit **300** that may include some of the same general constituents as FIG. 1. To that extent like items will be referred to the same reference character as FIG. 1.

20           FIG. 3 shows links arranged in the same general fashion as FIG. 1. However, unlike FIG. 1, a link **302-2** has been changed to a cross coupled state. In such a state, a signal path can be provided between a potential VPWR and a sense node **108**. This is in contrast to the configuration of FIG. 1, which may provide a signal path between a potential VGND and a sense node **108**.

As noted above, a cross coupled state may be represented by two, double throw switches being changed from a first thrown position to second thrown position.

FIG. 4 shows a series of top plan views showing links formed in various integrated circuit layers. FIG. 4 can correspond to the arrangement of FIG. 3. Further, FIG. 4 may include some of the same general constituents as FIG. 2. To that extent like items will be referred to the same reference character as FIG. 2.

5           FIG. 4 shows links arranged in the same general fashion as FIG. 2. However, unlike FIG. 2, a link **402-2** may include conductive lines **402-20** and **402-21** at a different orientation than in a previous mask version. For example, in FIG. 2, which may represent another mask version, a link **102-2** includes conductive lines **102-20** and **102-21** oriented in a first direction (horizontal in the figure). In contrast, in FIG. 4, a link **402-2** may include  
10       conductive lines **402-20** and **402-21** oriented in a second direction (vertical in the figure).

A comparison of FIGS. 1, 2 and 3, 4 shows a different value (i.e., the value at sense node **108**) may be provided to represent one mask change. However, as noted above, according to the present invention, a mask ID bit circuit may be switched between output values multiple times with multiple mask layers. To illustrate such a capability, a second  
15       mask version is shown by FIGS. 5 and 6.

FIGS. 5 and 6 can be conceptualized as showing another mask version change following that of FIGS. 3 and 4. More particularly, FIG. 5 shows a mask ID bit circuit **500** in which another link **502-3** (in addition to a link **302-2**) has been placed into a cross coupled state. As in the case of FIG. 3, a link **502-3** in a cross coupled state may be represented by  
20       two, double throw switches being switched from a directly coupled thrown position, to a cross coupled thrown position.

As shown in FIG. 5, due to a first cross coupling introduced by a link **302-2** and a second cross coupling introduced by a link **502-3**, a signal path can be provided between a

sense node **108** and a potential VGND. In this way, in one arrangement (that of FIG. 1), a signal path may be provided from a sense node **108** to a potential VGND. After a first modification (that of FIG. 3), a signal path may be provided from a sense node **108** to a potential VPWR. Then, after a second modification (that of FIG. 5), a signal path may once again be provided from a sense node **108** to a potential VGND. Thus, a mask ID bit circuit according the various embodiments illustrated by FIGS. 1, 3, 5 may alternate a resulting potential at a sense node as many times as there are links. That is, a potential at node **108** can be changed to the opposite state by changing any link.

FIG. 6 shows a series of top plan views showing links formed in various integrated circuit layers. FIG. 6 can correspond to the arrangement of FIG. 5. Further, FIG. 6 may include some of the same general constituents as FIG. 4. To that extent like items will be referred to the same reference character as FIG. 4.

FIG. 6 shows links arranged in the same general fashion as FIG. 4. However, unlike FIG. 4, a second link **502-3** may include conductive lines **602-30** and **602-31** at a different orientation than in a previous mask version. For example, in FIG. 2, which may represent another mask version, a link **102-2** may include conductive lines **102-20** and **102-21** oriented in a first direction (horizontal in the figure). In contrast, in FIG. 6, a two links **402-2** and **502-3** may include conductive lines **602-20** and **602-21** oriented in a second direction (vertical in the figure).

It is noted that in the example of FIGS. 2, 4 and 6, while conductive lines **402-20** and **402-21** may have a different orientation than a previously mask version, corresponding downward contact holes **204-20/21** and upward contact holes **206-20/21** may have the same general arrangement in all mask versions.

From the above description, it is understood that multiple mask ID bit circuits, such as those illustrated in FIGS. 1-6, can represent more possible mask versions than conventional cases. More particularly,  $n$  mask ID bit circuits may represent  $2^n$  possible mask versions with any combination of mask layer changes. As but one example, multiple mask ID bit circuits may have an arrangement such as that shown in FIG. 7.

It is understood that that the examples of FIGS. 1-6 represent but one possible progression of mask versions. That is, while FIGS. 1 and 2 show all links (102-0 to 102-4) and conductive lines (202-00 to 202-41) in the same configuration (e.g., all switches in a “down” position and all lines horizontal), such an arrangement does not necessarily have to represent an initial mask version. An initial mask version may have such links and conductive lines in an arbitrary configuration, with changes being made to such links to indicate a different mask version/revision.

It is also noted that the various examples of FIGS. 2, 4 and 6 show links directly on top of one another. Such an arrangement can provide for a mask ID bit circuit that consumes a small amount of circuit area. However, such a configuration should not be construed as limiting the invention thereto. Conductive lines could take different forms, being longer, being shorter, or having bends or the like, to name but a few variations.

Accordingly, it is understood that while various embodiments have been described in detail, the present invention could be subject various changes, substitutions, and alterations without departing from the spirit and scope of the invention. Accordingly, the present invention is intended to be limited only as defined by the appended claims.